WSDOT Field Tests of Wireless and Microwave Vehicle Detection Systems

2008 Western States Rural Transportation Technology Implementers Forum

Matt Neeley
ITS Research and Planning Engineer
Headquarters Traffic Design and Operations

Ted Bailey, PE
Signals, Illumination and ITS Engineer
Headquarters Traffic Design and Operations

Paula Hammond
Chief Executive Officer

David Dye
Chief Operating Officer

Mount Shasta, CA
June 3-5, 2008
Abstract

- The Washington State Department of Transportation (WSDOT) has implemented two field test sites in Olympia, WA for the sole purpose of testing various kinds of ITS equipment. One of the field test sites is equipped with a video surveillance system for monitoring site operations while both sites have a control cabinet, with a 50ft special design pole for hanging multiple devices, and a direct fiber connection back to our headquarters office for remote operation and data collection.

- As part of WSDOTs field research, tests have been completed at these two locations for Wavetronix, Speedinfo and Sensys Wireless Vehicle Detection Systems. Vehicle speeds and count data were collected side-by-side with data gathered from traditional loops or manual counts.

- The installation process, lessons learned along with the data comparison will be shared. The results of these tests have led to the deployment of Speedinfo and Sensys Network detection systems along the I-5 corridor and a planned deployments of a traffic signal systems with some or all Sensys Networks detection systems during the summer of 2008.
Location of WSDOT Field Test Sites

Olympia, WA

Test Site #2, SR 101

Test Site #1, I-5

WSDOT HQ Building

Aerial Fiber (Connects Test Sites to HQ Building)
WSDOT Field Test Site Equipment

Test Site #2, SR 101

- Controller and Service Cabinets
- 50ft Camera Pole
- Generator with automatic transfer switch
- Fiber / Communication Hub
- Loop Locations
- Sensys Network “Sensor” Locations
- Wavetronix Sensor Location
- Cohu CCTV Camera Location
- Pelco CCTV Camera Location
WSDOTs New Standard ITS Pole Foundation Design
ITS Field Test Site
Operations / Maintenance / Lessons Learned

1. $65 / Month Power Bill for 2 Controller Cabinets
2. Annual Budget for materials and installation $50k
3. Equipment Tested – Typically Donated or Loan
4. Installation - State forces ($200/hr for 2 people, bucket truck and traffic control)
5. Installation – Manufactures and vendors are typically present for installation
6. Issues with Partnering with IT and Contractors
WSDOT Field Test Site #1 – Interstate 5

- 50ft Camera Pole
- Controller Cabinet
- Fiber Hub
- Generator with automatic transfer switch
- Loops
WSDOT Field Test Site #1 – Interstate 5

Controller Cabinet (6 Strands)
Fiber Hub (288 Strands)
Generator with automatic transfer switch
Service
WSDOT Field Test Site #1 – Interstate 5

Cohu idome CCTV Camera
WSDOT Field Test Site #2 – SR 101

- 50ft Camera Pole
- Pelco CCTV Camera
- Controller Cabinet
- Sensys Networks Access Point Receiver (Hardwired back to the Controller)
Speedinfo Evaluation

DVSS-100 SENSOR SPECIFICATIONS

- **Sensor**
  - License free – 24.125GHz
  - Range 1800 ft, bi-directional
    - Single device measures both sides of roadway
  - Accuracy: 0.1mph, avg. +/- 3mph
  - Installs on existing infrastructure
    - Install time 30-45 minutes
  - Solar: 5W or 10W
    - Sealed lead acid batteries
    - 21 days of operation without photons
  - Weight: 16 lbs
    - Small profile, negligible wind loading
  - Programmable sampling rates
    - Default 2 measurements/minute
    - Adaptive reporting rates
  - Data Backhaul – ATT Wireless GPRS
    - Full Duplex
  - External Power and Communication port

- **Cost**
  - Option 1, Purchase with 3yr Maintenance, $4,200 per sensor
  - Option 2, Lease for $110 per month per sensor

- **Procurement**
  - Direct Buy IT Purchasing Authority
Speedinfo Installation
Everett

Everett to Marysville, Speed Info Sensor Locations

<table>
<thead>
<tr>
<th>Sensor Number</th>
<th>Road Name</th>
<th>Mile Post</th>
<th>Location Name</th>
<th>Equipment Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I-5 SB</td>
<td>189.89</td>
<td>I-5 S @ North of SR526/SR527 off ramp</td>
<td>In the Median on sign bridge</td>
<td>47.926662°</td>
<td>-122.203137°</td>
<td>North</td>
</tr>
<tr>
<td>2</td>
<td>I-5 SB</td>
<td>191.51</td>
<td>I-5 S @ Lowell Road overpass - Median</td>
<td>In the Median on Sign Bridge</td>
<td>47.946990°</td>
<td>-122.198282°</td>
<td>North</td>
</tr>
<tr>
<td>3</td>
<td>I-5 NB</td>
<td>193.45</td>
<td>I-5 N @ Pacific Avenue off ramp</td>
<td>On the Cantilever Sign</td>
<td>47.973894°</td>
<td>-122.191152°</td>
<td>South</td>
</tr>
<tr>
<td>4</td>
<td>I-5 SB</td>
<td>194.78</td>
<td>I-5 S @ East Marine View Drive on ramp</td>
<td>On the Camera Pole</td>
<td>47.990669°</td>
<td>-122.183017°</td>
<td>South</td>
</tr>
<tr>
<td>5</td>
<td>I-5 NB</td>
<td>196.41</td>
<td>I-5 N @ North of 12th Street NE</td>
<td>Right on the Wood Pole</td>
<td>48.013611°</td>
<td>-122.174167°</td>
<td>South</td>
</tr>
<tr>
<td>6</td>
<td>I-5 NB</td>
<td>197.67</td>
<td>I-5 N @ South of 40th Place NE</td>
<td>Right on the Wood Pole</td>
<td>48.031759°</td>
<td>-122.176864°</td>
<td>South</td>
</tr>
<tr>
<td>7</td>
<td>I-5 SB</td>
<td>198.50</td>
<td>I-5 S @ SR529 off ramp</td>
<td>In the gore area On Luminare Pole</td>
<td>48.043102°</td>
<td>-122.180861°</td>
<td>South</td>
</tr>
<tr>
<td>8</td>
<td>I-5 SB</td>
<td>199.35</td>
<td>I-5 S @ Marine Drive Northeast off ramp</td>
<td>In the Median on Sign Bridge</td>
<td>48.054944°</td>
<td>-122.184175°</td>
<td>North</td>
</tr>
<tr>
<td>9</td>
<td>I-5 NB</td>
<td>200.73</td>
<td>I-5 @ 88th Avenue on 88th Avenue Bridge</td>
<td>On the Luminare Pole at the Bridge</td>
<td>48.075651°</td>
<td>-122.184463°</td>
<td>South</td>
</tr>
<tr>
<td>10</td>
<td>I-5 NB</td>
<td>202.17</td>
<td>I-5 N @ 116th Street NE</td>
<td>Right On the Luminare Pole</td>
<td>48.096361°</td>
<td>-122.184199°</td>
<td>South</td>
</tr>
</tbody>
</table>
Speedinfo Installation
Everett - Map

- 10 sensor network
- 10 miles of coverage at 1 mile separation on I-5

Speedinfo Sensor
Speedinfo Evaluation - Everett
Speedinfo Evaluation - Everett

Speed Variance of 5.5% on average over a 24hr period in comparison to loops (2.9% to 15.1% range)

Speedinfo Sensor

Speedinfo vs Loops (Speed) North Bound

Speedinfo vs Loops (Speed) South Bound
Speedinfo Installation Nisqually Valley

- 10 sensor network
- 10 miles of coverage at 1 mile separation on I-5
Speedinfo Nisqually Valley – Flow Map

www.wsdot.wa.gov/Traffic/DuPont/
Speedinfo Evaluation – Lessons Learned

• Effects of Rain

• Location Limitations
  • Overpasses
  • Railroad tracks

• Frontage Roads
• Locations where Slower speeds can be detected
Speedinfo Data Processing

• XML Datafeed Example 1

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<speedInfo xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:type="speedInfo">
  <Speeds xsi:type="speedInfo-speeds">
    <System>SpeedInfo</System>
    <Version>1.0</Version>
    <DateTimeStamp xsi:type="date-timestamp">
      <Date>2008-04-30</Date>
      <Time>10:12:10</Time>
    </DateTimeStamp>
    <Units>US</Units>
    <DeviceData xsi:type="device-data">
      <DateTimeStamp xsi:type="date-timestamp">
        <Date>2008-04-30</Date>
        <Time>10:11:40</Time>
      </DateTimeStamp>
      <Id>10213</Id>
      <Status>OK</Status>
      <Confidence>100</Confidence>
      <Lane xsi:type="lane-data">
        <Id>ALL</Id>
        <Speed>61</Speed>
      </Lane>
    </DeviceData>
  </Speeds>
</speedInfo>
```
Speedinfo Data Processing

• XML Datafeed Example 2

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<speedInfo xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:type="speedInfo">
  <Setup xsi:type="speedInfo-setup">
    <System>SpeedInfo</System>
    <Version>1.0</Version>
    <DateTimeStamp xsi:type="date-timestamp">
      <Date>2008-04-29</Date>
      <Time>23:13:27</Time>
    </DateTimeStamp>
    <DeviceDescription xsi:type="device-description">
      <Id>10213</Id>
      <RoadName>I-5</RoadName>
      <RoadDir>N</RoadDir>
      <Latitude>48.075651</Latitude>
      <Longitude>-122.184463</Longitude>
    </DeviceDescription>
  </Setup>
</speedInfo>
```
Speedinfo Recommendations / Conclusions

1. Affordable ($110/month)
2. Simple Installation (30 min)
3. Installed by State Forces
4. Flow map Expansion
5. Use for determining travel time, can be used for posting travel times however correction factors will be required
6. Sensor can be moved and relocated as permanent Data Stations are built.
7. Sensor detects rain and averages rain with vehicle speeds, sensor is equipped with an algorithm that filters out the rain however, it takes two minutes for the sensor to correct itself and start reporting vehicle speeds only.
Sensys Networks

- Sensys magnetometers have been installed at two locations in place of loop detection for collecting speed, volume, occupancy and classification data.
Flush-Mount Wireless Sensors

- Magnetometer based detection
- Install using hammer or core drill
- 10 years of battery life
- Auto-calibration
- 2-way radio comms to access point – *uniquely addressable*
Sensys Networks

Sensor Vehicle Detection Zones

**Sensys vehicle detection zones are configurable, depending on the application**

<table>
<thead>
<tr>
<th>Traffic Lane</th>
<th>F</th>
<th>F'</th>
<th>R</th>
<th>R'</th>
<th>L</th>
<th>L'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway &amp; arterial applications</td>
<td>~0</td>
<td>~0</td>
<td>~4 feet / ~1.2 meters</td>
<td>~6 feet / ~1.8 meters</td>
<td>~2 feet / ~0.6 meters</td>
<td>~4 feet / ~1.2 meters</td>
</tr>
<tr>
<td>Stop bar detection@ stop bar #7</td>
<td>~6 feet / ~1.8 meters</td>
<td>~8 feet / ~2.4 meters</td>
<td>~6 feet / ~1.8 meters</td>
<td>~8 feet / ~2.4 meters</td>
<td>~3 feet / ~0.9 meters</td>
<td>~6 feet / ~1.8 meters</td>
</tr>
</tbody>
</table>
Sensys Networks

Sensys Access Point

**Access point relays sensor data to traffic controller or central servers**

- Simple Installation
- Processes, stores, and/or relays sensor data (Linux OS)
  - RS-485 to traffic controller
  - IP (fiber or cellular) to central servers
- Supports as many sensors as necessary
- Can serve as IP router for peripherals (video cams, etc.)
Sensys Networks

Sensys Repeater

*Repeater relays sensor data to access point*

- Battery-powered unit
- Supports up to 10 wireless sensors
- Relays detection data back to access point, extending range
- Supports mid-block detection – *no trenching required*
- Supports “geometrically complicated” installations
WSDOT Field Test of Sensys Networks

Test Site #2, SR 101

- Controller and Service Cabinets
- 50ft Camera Pole
- Loop Locations
- Sensys Network “Sensor” Locations

Access Point
Sensys Networks Installation
Sensys Networks
Installation
Sensys Networks
Installation

Video Clips

Sensys Networks Installation Video
Permanent Count Station (Freeways/Arterials)

Vehicle count, speed, occupancy and classification – just like inductive loops

WSDOT Field Test of Sensys Networks
WSDOT Field Test of Sensys Networks

Radio Ranges

access point - repeater max range ~ 1000 feet / 310 meters

access point - wireless sensor max range ~ 75-150 feet / 23-46 meters

repeater - wireless sensor max range ~ 75-150 feet / 23-46 meters
Sensys Networks

Standards-Based Radio Communications

*Sensys has adopted standard radio technology*

- **IEEE 802.15.4 PHY** – *used by ZigBee and other wireless systems*
  - Data rate of 250 kbps used by Sensys
  - 16 frequency channels in the 2.4 GHz ISM band

---

![IEEE 802.15.4 channels](image)

- Power efficiency is achieved by shutting down the radio entirely outside its assigned time slot (more than 99% of the time).
- **Sensys NanoPower (SNP) protocol**
  - Operates on top of 802.15.4 PHY as Media Access Protocol (MAC)
  - TDMA scheme allocates time slots for each sensor’s transmission
  - Access point acknowledges reception; each sensor re-transmits data is unacknowledged
RF Considerations

- AP, RP and sensors have directional antennas – propagation not uniform in all directions.

- AP to Repeater must be in line of sight.

- Up to 1000’ when directly facing each other.

- If they are off axis, distance will be shorter. Make sure of adequate signal strength.
SNAPS Manager

Communications, data analysis & archiving, and network management

- SNAPS Server = Sensys Networks Application, Proxy, and Statistics Server
  - Software for server platforms operating under Linux
  - Supported by standard Pentium class PC
- Supports IP connectivity to network of Sensys access points
  - VPN
  - Proxy
  - Facilitates use of cellular data services to provide IP connectivity to APs
- Data archiving
- Supports Internet user access to data
- Push/Poll capability to other applications
- Hosts application-level analysis software
Stop Bar Detection

- Wireless sensors can be deployed just like inductive loops
  - Presence detection at/near stop bar
  - Queue detection in turn lanes
- Access point interfaces directly to traffic controller using contact closure cards
  - Presence or pulse modes
  - Sensors in same lane can be OR’ed together
Advance Detection

- Wireless sensors located mid-block
  - Traffic calming
  - Dilemma zone protection
- Access point interfaces directly to traffic controller
- Repeaters extend access point range from traffic controller to mid-block locations
Serial Interface to Traffic Controllers

Interoperable with current roadside infrastructure

- Type 170
- Type 2070
- NEMA TS1
- NEMA TS2
Sensys Networks – Traffic Signal

Contact Closure (CC) & Expansion (EX) Cards

*Allow use of Sensys wireless sensors exactly like inductive loops*

- One CC card per Access Point
  - Up to 4 channels (i.e., 4 contact closures) per card
  - Provides power and electrical isolation to Sensys access point.

- Additional EX cards as required (4 channels per card)
Sensys Networks – Evaluation

Volume

- Manual Counts
- Loops
- Sensys

Variance from Manual Counts

<table>
<thead>
<tr>
<th>Time</th>
<th>Manual Counts</th>
<th>Loops</th>
<th>Sensys</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Manual, 1389</td>
<td>Sensys, 1353</td>
<td>ADC, 1314</td>
</tr>
<tr>
<td>10:00</td>
<td>Manual, 1428</td>
<td>Sensys, 1387</td>
<td>ADC, 1487</td>
</tr>
<tr>
<td>11:00</td>
<td>Manual, 1568</td>
<td>Sensys, 1385</td>
<td>ADC, 1568</td>
</tr>
</tbody>
</table>

- Loops 5.2%
- Sensys 11.7%
- Loops 6.7%
- Sensys 2.9%
- Loops 5.4%
- Sensys 2.6%
Sensys Networks – Evaluation

Sensys vs Loops (Volume)

Volume (Vehicles/hr)

TIME (Hrs.)

2.49% Average Variance
Sensys Networks – Evaluation

Sensys vs Loops (AVERAGE SPEED)

<table>
<thead>
<tr>
<th>TIME</th>
<th>Sensys Avg Speed</th>
<th>Loops Avg Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00:00</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>03:00:00</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>06:00:00</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>09:00:00</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>12:00:00</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>15:00:00</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>18:00:00</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>21:00:00</td>
<td>54</td>
<td>54</td>
</tr>
</tbody>
</table>

1.0% Average Variance
Sensys Networks

- **Cost**
  - **Flush-Mount Wireless Sensor**
    - $460 each
    - Install - $2,000 for 8 sensors
    - In 4 lanes / 4hrs
  - **Access Point (GRPS Model)**
    - $3,600 each
  - **Repeater**
    - $625 each
  - **Controller interface**
    - $296 each
    - (each card simulates 4 contact closures)

- **Procurement**
  - State General Administration Contact – Direct buy from McCain
Sensys Networks Recommendations / Conclusions

1. Equipment set up is straightforward with online manuals and phone support. 1st time set up took 3½ hrs to configure the A/P and Sensors.

2. Installation took 20 min per lane not including traffic control set up, our State force crew averaged 1 hour per lane including traffic control.

3. Quality of data when pulled from the SNAPS server was better than 97% for speed and Volume

4. SNAP Server Limitations

5. Quality of Data when run through a Diamond Counter and Sensys Contact Closure Cards was not measurable as the Diamond Counter is not compatible with this system.

6. The Sensys system will be tested against loops for intersection control, (i.e. Stop Bar Detection and Queue Detection).
Wavetronix Evaluation

- 50ft Camera Pole
- Loop Locations
- Wavetronix Sensor Location

Test Site #1, I-5
Wavetronix Evaluation

- Cost, $10,000-$20,000 depending on utilities (power & com)
- Simple Installation and calibration
- Concrete barrier caused challenges in environment for the sensor (Splash)
- Occlusion is a major factor in volume error’s in area with higher truck volumes
Click 100

- Collects real time traffic data
- Has 16 outputs to emulate up to 8 lanes of two-loop data
- Auto-detection of baud rates and sensor configuration
- Pluggable screw terminals
- DIN rail mounted
- Hot-swappable power and communication buses
- Multiple modes of operation
- Front panel LEDs provide visual confirmation of vehicle detections
- Low power device
Wavetronix Evaluation
Loops vs Wavetronix and RTMS

7/19 RTMS and SmartSensor COMPARISON

RTMS from EIS

Wavetronix

HOUR

PERCENT DIFFERENCE

% Difference TDO Loops and RMTS
% Difference TDO Loops and Wavetronix
Wavetronix Evaluation

Wavetronix vs Loops (Volume)

22% average variance
Wavetronix Conclusions / Recommendations

1. 95% accuracy for speed and volume (at right locations)
2. Initial set up was done with manufacture and was done in less than 2 hour
3. Not recommended for locations with divided concrete barrier, concrete walls or structures.
4. Wavetronix was set up on a 8 lane highway separated with a concrete barrier and a concrete retaining wall 200ft from the sensor and the sensor operated at 75-80%
5. Wavetronix works well in the right location for providing Speed and Volume data, however requires monthly power and communication service
Cohu idome Demonstration
Sensys Networks Archive, Proxy, and Statistics (SNAPS) Server Demonstration